

High School Environmental Science

Core Content



Office of Math and Science Education
New Jersey Department of Education

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Course Focus: An Environmental Science course is designed to immerse students in the physical, biological, and earth systems sciences that shape our environment. Scientific concepts, principles and modern science practices allow students to analyze environmental issues, both natural and human induced, and engage in evidence-based decision making in real world contexts.

Mission of Science Education: *Scientifically literate students possess the knowledge and understanding of scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic productivity.*

Vision of Science Education: A quality science education fosters a population that:

- Experiences the richness and excitement of knowing about the natural world and understanding how it functions.
- Uses appropriate scientific processes and principles in making personal decisions.
- Engages intelligently in public discourse and debate about matters of scientific and technological concern.
- Applies scientific knowledge and skills to increase economic productivity.

What is a Laboratory/Inquiry-Based Science Course?

We begin to answer this question by stating that Laboratory science is a practice not a place. Laboratory/inquiry-based science courses (lab course) emphasize student sense making opportunities rather than focusing on course title or seat time.

Next, we look at the question from a structure and function perspective. The function of our K-12 science instruction should be students becoming scientifically proficient. The definition of proficiency has evolved over the past several years. Knowing science requires individuals to integrate a complex structure of many types of knowledge. These knowledge types include the ideas of science, the relationships between the ideas, the reasons for these relationships, and the ways to use these ideas to complete the following tasks: explain and predict other phenomena, interpret situations, solve problems and participate productively in science practice and discourse (ACT, 2007; College Board, 2009; NJCCCS, 2009). Therefore rigorous instruction must evolve from a focus on learning all of the facts and specific examples about a concept to an understanding and application of core principles of the discipline and an integration of that knowledge with the processes that are necessary for practicing science discourse (ACT, 2007; College Board, 2009; NJCCCS, 2009). The requirement that all high school science courses to be laboratory/inquiry-based reflects the importance of the necessity for each of us to examine how well our instructional practices are likely to result in our students becoming scientifically literate.

From an academic perspective, contemporary views of learning prize understanding and application of knowledge in use. Learners who understand can use and apply novel ideas in diverse contexts, drawing connections among multiple representations of a given concept. They appreciate the foundations of knowledge and consider the evidence for claims. Accomplished learners know when to ask a question, how to challenge claims, where to go to learn more, and they are aware of their own ideas and how these change over time. (2007, NRC)

The classic scientific method as taught for many years provides only a very general approximation of the actual working of scientists. The process of theory development and testing is iterative, uses both deductive and inductive logic, and incorporates many tools besides direct experiment. Modeling (both mechanical models and computer simulations) and scenario building (including thought experiments) play an important role in the development of scientific knowledge. The ability to examine one's own knowledge and conceptual frameworks, to evaluate them in relation to new information or competing alternative frameworks, and to alter them by a deliberate and conscious effort are key scientific practices. (2007, NRC)

The process by which scientific understandings are developed and the form that those understandings take differ from one domain of science to another, but all sciences share certain common features at the core of their problem-solving and inquiry approaches. Chief among these is that data and evidence hold a primary position in deciding any

issue. Thus, when well-established data, from experiment or observation, conflict with a theory or hypothesis, then that idea must be modified or abandoned and other explanations must be sought that can incorporate or take account of the new evidence. This also means that models, theories, and hypotheses are valued to the extent that they make testable (or in principle testable) precise predictions for as yet unmeasured or unobserved effects; provide a coherent conceptual framework that is consistent with a body of facts that are currently known; and offer suggestions of new paths for further study. (2007, NRC)

A process of argumentation and analysis that relates data and theory is another essential feature of science. This includes evaluation of data quality, modeling, and development of new testable questions from the theory, as well as modifying theories as data dictates the need. Finally, scientists need to be able to examine, review, and evaluate their own knowledge. Holding some parts of a conceptual framework as more or less established and being aware of the ways in which that knowledge may be incomplete are critical scientific practices. (2007, NRC)

Lab science courses emphasize the importance of students independently creating scientific arguments and explanations for observations made during investigations. Science courses thereby become a sense-making enterprise for students in which they are systematically provided with ongoing opportunities to:

- Interact directly with the natural and designed world using tools, data-collection techniques, models, and theories of science.
- Actively participate in scientific investigations and use cognitive and manipulative skills associated with the formulation of scientific explanations.
- Use evidence, apply logic, and construct arguments for their proposed explanations.

The lab science requirement implicitly and explicitly point to a more student-centered approach to instructional design that engages learners in inquiry. Inquiry, as defined in the revised standards, envisions learners who:

- Are engaged by scientifically-oriented questions.
- Prioritize evidence that addresses scientifically-oriented questions.
- Formulate explanations from that evidence to address those scientifically-oriented questions.
- Evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
- Communicate and justify their proposed explanations.

Fundamental principles of lab science course design assist students in achieving science proficiency through sense making experiences that:

- Are designed with clear learning outcomes in mind.
- Are sequenced thoughtfully into the flow of classroom science instruction.
- Integrate learning of science content with learning about science practices.
- Incorporate ongoing student reflection and discussion (National Research Council, 2007).

If lab science is a practice not a place, then what kinds of things should my students be doing in a lab science course? Students' K-12 lab science experiences should include the following:

- **Physical manipulation of authentic substances or systems:** This may include such activities as chemistry experiments, plant and animal observations, and investigations of force and motion.
- **Interaction with simulations:** In 21st century laboratory science courses, students can work with computerized models, or simulations, that represent aspects of natural phenomena that cannot be observed directly because

they are very large, very small, very slow, very fast, or very complex. Students may also model the interaction of molecules in chemistry or manipulate models of cells, animal or plant systems, wave motion, weather patterns, or geological formations using simulations.

- **Interaction with authentic data:** Students may interact with authentic data that are obtained and represented in a variety of forms. For example, they may study photographs to examine characteristics of the moon or other heavenly bodies or analyze emission and absorption spectra in the light from stars. Data may be incorporated in films, DVDs, computer programs, or other formats.
- **Access to large databases:** In many fields of science, researchers have arranged for empirical data to be normalized and aggregated—for example, genome databases, astronomy image collections, databases of climatic events over long time periods, biological field observations. Some students may be able to access authentic and timely scientific data using the Internet and can also manipulate and analyze authentic data in new forms of laboratory experiences (Bell, 2005).
- **Remote access to scientific instruments and observations:** When available, laboratory experiences enabled by the Internet can link students to remote instruments, such as the environmental scanning electron microscope (Thakkar et al., 2000), or allow them to control automated telescopes (Gould, 2004).

Sometimes, administrative code language (structure) issued from the NJDOE results in a compliance approach to meeting the requirements rather than an approach based on the spirit and intent of the language. It is often preferable to provide teachers with the expectations for outcomes (function). In the process of transforming your course, remain focused on the desired result of student proficiency. Knowing science requires individuals to integrate a complex structure of many types of knowledge. These knowledge types include the ideas of science, the relationships between the ideas, the reasons for these relationships, and the ways to use these ideas to complete the following tasks: explain and predict other phenomena, interpret situations, solve problems and participate productively in science practice and discourse (ACT, 2007; College Board, 2009; NJCCCS, 2009). Therefore rigorous instruction must evolve from a focus on learning all of the facts and specific examples about a concept to an understanding and application of core principles of the discipline and an integration of that knowledge with the processes that are necessary for practicing science discourse (ACT, 2007; College Board, 2009; NJCCCS, 2009). The requirement that all high school science courses to be laboratory/inquiry- based reflects the importance of the necessity for each of us to examine how well our instructional practices are likely to result in our students becoming scientifically literate.

Environmental Science Core Content Outline:

B. Matter and Energy Transformations: Food is required for energy and building cellular materials. Organisms in an ecosystem have different ways of obtaining food, and some organisms obtain their food directly from other organisms.

1. As matter cycles and energy flows through different levels of organization within living systems (cells, organs, organisms, communities), and between living systems and the physical environment, chemical elements are recombined into different products.
2. Each recombination of matter and energy results in storage and dissipation of energy into the environment as heat.
3. Continual input of energy from sunlight keeps matter and energy flowing through ecosystems.

C. Properties of Earth Materials: Earth's composition is unique, is related to the origin of our solar system, and provides us with the raw resources needed to sustain life.

1. Soils are at the interface of the Earth systems, linking together the biosphere, geosphere, atmosphere, and hydrosphere. Soils are at the interface of the Earth systems, linking together the biosphere, geosphere, atmosphere, and hydrosphere.
2. The chemical and physical properties of the vertical structure of the atmosphere support life on Earth.

F. Climate and Weather: Earth's weather and climate systems are the result of complex interactions between land, ocean, ice, and atmosphere.

1. Climate is determined by energy transfer from the Sun at and near Earth's surface. This energy transfer is influenced by dynamic processes, such as cloud cover and Earth's rotation, as well as static conditions, such as proximity to mountain ranges and the ocean. Human activities, such as the burning of fossil fuels, also affect the global climate.
2. The chemical and physical properties of the vertical structure of the atmosphere support life on Earth.

G. Biogeochemical Cycles: The biogeochemical cycles in the Earth systems include the flow of microscopic and macroscopic resources from one reservoir in the hydrosphere, geosphere, atmosphere, or biosphere to another, are driven by Earth's internal and external sources of energy, and are impacted by human activity.

1. Natural and human-made chemicals circulate with water in the hydrologic cycle.
2. Natural ecosystems provide an array of basic functions that affect humans. These functions include maintenance of the quality of the atmosphere, generation of soils, control of the hydrologic cycle, disposal of wastes, and recycling of nutrients.
3. Energy in Biogeochemical Systems: Movement of matter through Earth's system is driven by Earth's internal and external sources of energy and results in changes in the physical and chemical properties of the matter.
4. Human Influences: Natural and human activities impact the cycling of matter and the flow of energy through ecosystems.
5. Human Activities: Human activities have changed Earth's land, oceans, and atmosphere, as well as its populations of plant and animal species.
6. Evidence Based Decision Making: Scientific, economic, and other data can assist in assessing environmental risks and benefits associated with societal activity.
7. Conservation of Matter: Earth is a system in which chemical elements exist in fixed amounts and move through the solid Earth, oceans, atmosphere, and living things as part of geochemical cycles.

Science Practices:

A. Understand Scientific Explanations: Students understand core concepts and principles of science and use measurement and observation tools to assist in categorizing, representing, and interpreting the natural and designed world.

1. Mathematical, physical, and computational tools are used to search for and explain core scientific concepts and principles.
2. Interpretation and manipulation of evidence-based models are used to build and critique arguments/explanations.
3. Revisions of predictions and explanations are based on systematic observations, accurate measurements, and structured data/evidence.

B. Generate Scientific Evidence Through Active Investigations: Students master the conceptual, mathematical, physical, and computational tools that need to be applied when constructing and evaluating claims.

1. Logically designed investigations are needed in order to generate the evidence required to build and refine models and explanations.
2. Mathematical tools and technology are used to gather, analyze, and communicate results.
3. Empirical evidence is used to construct and defend arguments.
4. Scientific reasoning is used to evaluate and interpret data patterns and scientific conclusions.

C. Reflect on Scientific Knowledge: Scientific knowledge builds on itself over time.

1. Refinement of understandings, explanations, and models occurs as new evidence is incorporated.
2. Data and refined models are used to revise predictions and explanations.
3. Science is a practice in which an established body of knowledge is continually revised, refined, and extended as new evidence emerges.

D. Participate Productively in Science: The growth of scientific knowledge involves critique and communication, which are social practices that are governed by a core set of values and norms.

1. Science involves practicing productive social interactions with peers, such as partner talk, whole-group discussions, and small-group work.
2. Science involves using language, both oral and written, as a tool for making thinking public.
3. Ensure that instruments and specimens are properly cared for and that animals, when used, are treated humanely, responsibly, and ethically.

Understanding the Structure and Function of this Document

Standard: The Standard outlines the core understanding for each content domain. Each standard statement explains why the strands and cumulative progress indicators are important.	
Strand: The strand defines a core concept or principle in environmental science. Each strand runs throughout students' K-12 academic experience. Each of the life science strands supports the core understanding of the Standard.	
Essential Questions	Enduring Understandings
These questions have no 'right' or 'easy' answer, and are meant to inspire investigation and raise more questions.	These understandings are insights that a student gains through learning experiences, and are transferable to new situations.
Content Statements	Cumulative Progress Indicators
These statements describe the environmental science concept/content that a student needs to understand.	These statements describe how students can demonstrate their understanding of the concept/content.
<p>Instructional Focus:</p> <ul style="list-style-type: none"> Provides further clarification of the learning expectations for curriculum developers, teacher, assessment panels, and students Offers suggestions for scaffolding for instruction Provides boundaries for the content included in an Environmental Science End of Course Assessment <ul style="list-style-type: none"> <i>Narratives identified with this symbol are details that will not be part of the statewide assessments.</i> <p>Common Student Misconceptions:</p> <p>Current research in science education emphasizes the importance of knowing students' previous ideas, conceptions, and representations of scientific content. This research also identifies a considerable number and variety of student misconceptions regarding natural processes and systems, while also reporting the complexity of transforming such mistaken ideas or conceptions. Uncovering students' misconceptions are an important issue for the development of teaching strategies and for identifying students' conceptual progress. In an attempt to bridge these gaps, Common Student Misconceptions was included in this document to help you address these obstacles to student understanding of environmental science content.</p> <p>Sample Assessment Item:</p> <p>These items have been provided to give you a sample of the types of items that students should be able to answer in a locally developed benchmark assessment. These items can be used on classroom assessments or as samples for the creation of school or district items during an exercise in professional development.</p> <p>Sample Integration of Science Practices and Core Content:</p> <p>The 2009 Science Standards implicitly and explicitly point to a more student-centered approach to instructional design that engages learners in inquiry. Inquiry, as defined in the revised standards, envisions learners who are engaged by scientifically-oriented questions; prioritize evidence that addresses scientifically-oriented questions; formulate explanations from that evidence to address those scientifically-oriented questions; evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding; and communicate and justify their proposed explanations. The Sample Integration of Science Practices and Core Content is a brief sample description of a learning experience that integrates the environmental science content with the science practices. These experiences can be modified to meet the needs of your students.</p> <p>Resources:</p> <p>The National Science Digital Library (NSDL) was created by the National Science Foundation to provide organized access to high quality resources and tools that support innovations in teaching and learning at all levels of science, technology, engineering, and mathematics (STEM) education. NSDL provides an organized point of access to high-quality STEM content from a variety of other digital libraries, NSF-funded projects, and NSDL-reviewed web sites.</p>	

5.3 Life Science: Life science principles are powerful conceptual tools for making sense of the complexity, diversity, and interconnectedness of life on Earth. Order in natural systems arises in accordance with rules that govern the physical world, and the order of natural systems can be modeled and predicted through the use of mathematics.

B. Matter and Energy Transformations: Food is required for energy and building cellular materials. Organisms in an ecosystem have different ways of obtaining food, and some organisms obtain their food directly from other organisms.

Essential Questions	Enduring Understandings
To what extent does understanding the flow of matter and energy through living systems effect personal and public policy decisions?	All organisms transfer matter and convert energy from one form to another. Both matter and energy are necessary to build and maintain living systems.
Content Statements	Cumulative Progress Indicators
As matter cycles and energy flows through different levels of organization within living systems (cells, organs, organisms, communities), and between living systems and the physical environment, chemical elements are recombined into different products.	Cite evidence that the transfer and transformation of matter and energy links organisms to one another and to their physical setting. (5.3.12.B.1)

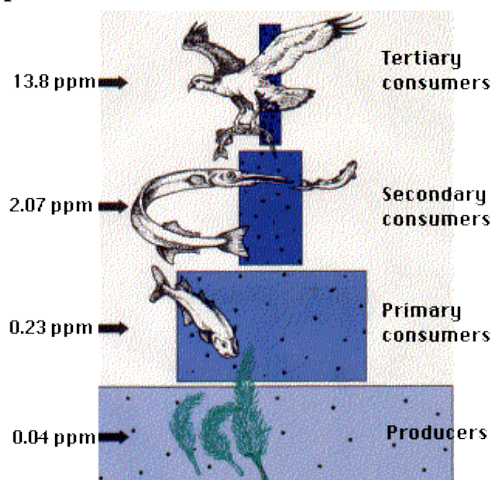
Instructional Focus:

- The chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways (photosynthesis, respiration, nitrogen fixation, or decomposition). *BMSL 5E/H3; NAAEE 2.1.B.2*
- At each link in a food web, some energy is stored in newly made structures but much is dissipated into the environment. Continual input of energy from sunlight keeps the process going. *BMSL 5E/H3; NAAEE 2.1.B.2*

Common Student Misconceptions:

Research indicates that few students are able to relate their ideas about feeding and energy to a framework of ideas about interactions of organisms. Many students do not recognize how organisms are connected in terms of feeding and energy, and many students cannot explain why humans cannot live in a world without plants (Smith and Anderson 1986). You can determine if students harbor this misconception by asking students to justify the statements 'all life **depends** on green plants' using scientific explanations. Students reporting that plants harness solar energy through photosynthesis, recognizing the inability of animals to 'make their own food'.

Sample Assessment Item:



The numbers are representative values of the concentration in the tissues of DDT and its derivatives (in parts per million, ppm)

Use the image to the left to answer the following question:

The image to the left is a stylized food web that illustrates the biomagnification of DDT. DDT is rapidly taken up but only slowly eliminated from the body by fish and other aquatic organisms, so each step up in the food web magnifies the concentration from the step below.

- How could this image and the concept of biomagnification be used to illustrate that the transfer and transformation of matter links organisms to one another and to their physical setting?

2. Use your knowledge of the nitrogen cycle to describe how one atom of nitrogen could travel through and interact with: an animal, soil, a plant, a bacterium or bacteria, and the air.
3. Mercury released from coal burning power plants ends up in the ocean at very tiny concentrations. Yet eating salmon is not recommended for pregnant women because of the high concentration of mercury in these oceanic fish. How can the fish end up with high levels of mercury if the water they live in has such low levels of mercury?
4. If salmon eat smaller fish, the smaller fish eat zooplankton (tiny animals), and the zooplankton eat phytoplankton (tiny plants) then what would the level of mercury be in the salmon compared to the phytoplankton?
 - A. $1/10^{\text{th}}$
 - B. The same
 - C. 10 x
 - D. 100 x
 - E. 1000 x

Resources:

National Science Digital Library, Science Digital Literacy Maps

The Living Environment: Flow of Matter in Ecosystems:

<http://strandmaps.nsdli.org/?id=SMS-MAP-9001>

The Living Environment: Flow of Energy in Ecosystems:

<http://strandmaps.nsdli.org/?id=SMS-MAP-1422>

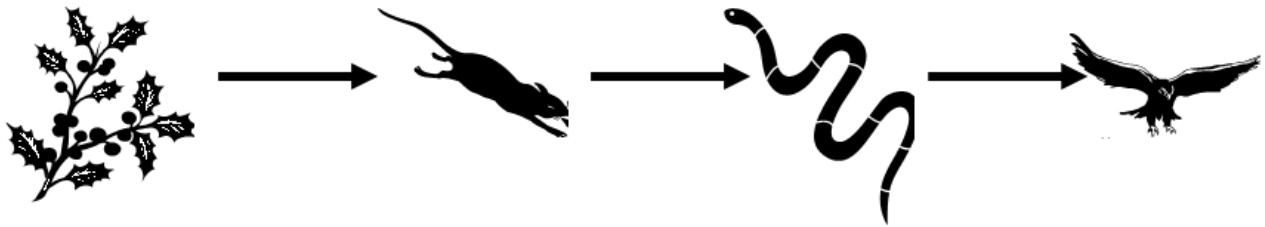
Science Curriculum Topic Study: Cycling of Matter in Ecosystems, p. 124

Flow of Energy Through Ecosystems, p. 128

Content Statements	Cumulative Progress Indicators
Each recombination of matter and energy results in storage and dissipation of energy into the environment as heat.	Use mathematical formulas to justify the concept of an efficient diet. (5.3.12.B.2)
<p>Instructional Focus:</p> <ul style="list-style-type: none"> Although the various forms of energy appear very different, each can be measured in a way that makes it possible to keep track of how much of one form is converted into another. Whenever the amount of energy in one place diminishes the amount in other places or forms increases by the same amount. <i>4E/HI</i> The use and transfer of energy from one trophic level to another can be calculated. <ul style="list-style-type: none"> Rule of Ten <p>Common Student Misconceptions:</p> <p>Research indicates that some students mistakenly believe that energy is associated only with humans or movement, is a fuel-like quantity which is used up, or is something that makes things happen and is expended in the process. Students rarely think energy is measurable and quantifiable (Solomon 1985). You can determine if students harbor this misconception by asking students to clearly explain the differences between energy and other concepts such as food, force, and temperature.</p> <p>Sample Assessment Item:</p> <ol style="list-style-type: none"> You are living on an island with one hundred other people. They have asked you, as a scientist, to help them make an important decision. There is a limited amount of land to grow crops. The land is currently growing corn and beans. There are also several cows on the island, enough to establish a herd if you so desire. You can 	

either continue planting corn and beans and eating them directly or use some or all of the corn and beans that you grow to raise more cows for milk and meat. There is no possibility of leaving the island or getting any supplies from elsewhere. Fishing is not an option. Use your knowledge of how matter and energy move through ecosystems to describe what you would recommend doing in response to your fellow islanders request for advice. Use a mathematical argument to help make your point.

2. Some vegetarians argue that their choice of diet is not just a moral but an environmental good. Argue for or against this point of view using your knowledge of how matter and energy move through ecosystems. Use a mathematical argument to help make your point.



3. In the food chain above, if there are 1 kg of snakes then there is probably _____ kg of vegetation.
- 1000
 - 100
 - 10
 - 1
 - .1

Resources:

National Science Digital Library, Science Digital Literacy Maps

The Living Environment: Flow of Matter in Ecosystems:

<http://strandmaps.nsdli.org/?id=SMS-MAP-9001>

The Living Environment: Flow of Energy in Ecosystems:

<http://strandmaps.nsdli.org/?id=SMS-MAP-1422>

Science Curriculum Topic Study: Food Chains and Food Webs, p. 129

Additional Resource:

NOAA's [The Earth's Energy Budget](http://oceanservice.noaa.gov/education/lessons/earth_energy_budget_demo.html) Demonstration: The three types of heat transfer and the processes that light as radiation can undergo: reflection, absorption, and refraction.

http://oceanservice.noaa.gov/education/lessons/earth_energy_budget_lesson.html

Content Statements	Cumulative Progress Indicators
Continual input of energy from sunlight keeps matter and energy flowing through ecosystems.	Predict what would happen to an ecosystem if an energy source was removed. (5.3.12.B.3)
Instructional Focus: <ul style="list-style-type: none"> The chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. At each link in a food web, some energy is stored in newly made structures but much is dissipated into the environment. Continual input of energy from sunlight keeps the process going. 5E/H3 Living systems require a continuous input of energy to maintain their chemical and physical organizations and also 	

understanding that with the cessation of energy input, living systems rapidly disintegrate.

- The abundance and distribution of living organisms are limited by the available energy and certain forms of matter such as water, oxygen and minerals. (NAAEE 2.2.D.3)

Common Student Misconceptions:

Research indicates that some students have difficulty in identifying the sources of energy for plants and animals. Some students confuse the concept of energy with other concepts such as food, force, and temperature. As a result, these students may not appreciate the uniqueness and importance of specific energy conversion processes like respiration and photosynthesis (Anderson et al. 1990). You can determine if students harbor this misconception by asking students to explain in detail how energy is transferred and transformed at each interaction in a food web.

Students often think that plant cells photosynthesize and that only animal cells utilize cellular respiration.

Sample Assessment Item:

1. Sunlight is necessary for photosynthesis by plants that are the base of almost every food web. Without sunlight photosynthesis stops and the whole food chain collapses. If this is true, how can a community of organisms live in a lightless subterranean cave?
2. Europa is a moon of the planet Jupiter. Like all the gas giant planets Jupiter has a much more distant orbit from the center of the solar system than Earth. Though there may be, or have been, liquid water beneath the frozen crust of the surface of the moon there is not likely to have been, or to be, much life on this moon. Since liquid water and nutrients may be plentiful, why would we not expect to find a productive ecosystem on Europa? What is missing?

Resources:

National Science Digital Library, Science Digital Literacy Maps

The Living Environment: Flow of Matter in Ecosystems:

<http://strandmaps.nsdl.org/?id=SMS-MAP-9001>

The Living Environment: Flow of Energy in Ecosystems:

<http://strandmaps.nsdl.org/?id=SMS-MAP-1422>

Science Curriculum Topic Study: Food Chains and Food Webs, p. 129

5.4 Earth Systems Science: All students will understand that Earth operates as a set of complex, dynamic, and interconnected systems, and is a part of the all-encompassing system of the universe.	
C. Properties of Earth Materials: Earth's composition is unique, is related to the origin of our solar system, and provides us with the raw resources needed to sustain life.	
Essential Questions	Enduring Understandings
Why is it important to think in terms of systems of systems when considering environmental issues?	Ecosystems are the result of the interactions among Earth's biosphere, geosphere, atmosphere, and hydrosphere.
Content Statements	Cumulative Progress Indicators
Soils are at the interface of the Earth systems, linking together the biosphere, geosphere, atmosphere, and hydrosphere.	Model the interrelationships among the spheres in the Earth systems by creating a flow chart. (5.4.12.C.1)
Instructional Focus: <ul style="list-style-type: none"> The transfer of matter and energy between the biosphere, geosphere, atmosphere, and hydrosphere often takes place in soils. <ul style="list-style-type: none"> The unconsolidated mineral or organic material on the immediate surface of the Earth that serves as a natural medium for the growth of land plants. The unconsolidated mineral or organic matter on the surface of the Earth that has been subjected to and shows effects of genetic and environmental factors of: climate (including water and temperature effects), and macro- and microorganisms, conditioned by relief, acting on parent material over a period of time. A product-soil differs from the material from which it is derived in many physical, chemical, biological, and morphological properties and characteristics. (US Department of Agriculture, Viewed August 24, 2010, http://soils.usda.gov/education/facts/soil.html) Earth's atmosphere exchanges energy and matter within the Earth System through processes such as photosynthesis, the water cycle, biogeochemical cycles, the rock cycle and ocean currents. 5.1 (NOAA, 2008). The four major systems of Earth are the geosphere, hydrosphere, atmosphere, and biosphere. The geosphere includes a metallic core, solid and molten rock, soil, and sediments. The atmosphere is the envelope of gas surrounding Earth. The hydrosphere includes the ice, water vapor, and liquid water in the atmosphere, the ocean, lakes, streams, soils, and groundwater. The biosphere includes Earth's life, which can be found in many parts of the geosphere, hydrosphere, and atmosphere. Humans are part of the biosphere, and human activities have important impacts on all four spheres. 3.1 (NSF, 2009). Common Student Misconceptions: <p>It is common for students to believe that soil is 'just dirt' or any 'stuff on the ground.' Students appear to be largely unaware that there are living organisms in the soil and unaware of the role of the living organisms in the soil. The formation of soil is strongly associated with deposition by rivers results from volcanic activity, or that soil is the precursor to rock (Happs).</p> <p>Some think dead organisms simply rot away. They do not realize that the matter from the dead organism is converted into other materials in the environment. Some students see decay as a gradual, inevitable consequence of time without need of decomposing agents (Smith, E., Anderson, C., 1986). Some high-school students believe that matter is conserved during decay, but do not know where it goes (Leach, J., Driver, R., Scott, P., Wood-Robinson, C., 1992).</p> <p>Students seem to know that some kind of cyclical process takes place in ecosystems (Smith, E., Anderson, C., 1986). Some students see only chains of events and pay little attention to the matter involved in processes such as plant growth or animals eating plants. They often think in linear terms and have trouble reasoning about cycles or systems that have multiple inputs and outputs (Jordan, R.C., Gray, S., Demeter, M., Lui, L., Hmelo-Silver, C. 2009). They</p>	

think the processes involve creating and destroying matter rather than transforming it from one substance to another. Other students recognize one form of recycling through soil minerals but fail to incorporate water, oxygen, and carbon dioxide into matter cycles. Even after specially designed instruction, students cling to their misinterpretations. Instruction that traces matter through the ecosystem as a basic pattern of thinking may help correct these difficulties (Smith, E., Anderson, C., 1986).

Sample Integration of Science Practices and Core Content:

Objectively discern scientific consensus versus other agendas present in the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report published in the July 20, 2001 issue of the journal Science. Evaluate and report on the credibility and credentials of the authoring organizations and their use of data. The Atmosphere and Climate Change http://esa21.kennesaw.edu/activities/atmosphere/atms_climatechange.pdf

Sample Assessment Item:

1. You have been provided three soil samples from the Moon and Mars. Your task is to examine the properties of the sample and identify Students will then examine and test unknown soil samples and record test observations. Using the charts, each unknown sample will be identified. Students will be asked to defend their decisions.

Resources:

National Science Digital Library, Science Digital Literacy Maps

The Physical Setting: Weather and Climate: <http://strandmaps.nsdl.org/?id=SMS-MAP-1698>

The Physical Setting: Changes in the Earth's Surface <http://strandmaps.nsdl.org/?id=SMS-MAP-0048>

Common Themes: Systems: <http://strandmaps.nsdl.org/?id=SMS-MAP-1594>

Science Curriculum Topic Study: Soil, p. 186

Other Web Based Resources

National Science Foundation, (2009), Earth Science Literacy Principles. Published May 2009, retrieved August 2010. <http://www.earthscienceliteracy.org/>

National Science Foundation, National Oceanic and Atmospheric Administration, (2008). Essential Principles and Fundamental Concepts for Atmospheric Science Literacy. Published October 2008, retrieved August 2010. <http://eo.ucar.edu/asl/index.html>

Content Statements	Cumulative Progress Indicators
The chemical and physical properties of the vertical structure of the atmosphere support life on Earth.	Analyze the vertical structure of Earth's atmosphere, and account for the global, regional, and local variations of these characteristics and their impact on life. (5.4.12.C.2)
Instructional Focus: <ul style="list-style-type: none"> Life is adapted to conditions on the earth, including the force of gravity that enables the planet to retain an adequate atmosphere, and an intensity of electromagnetic waves from the sun that allows water to be present in the liquid state. 4B/H1 (BSL) Greenhouse gases in the atmosphere, such as carbon dioxide and water vapor, are transparent too much of the incoming sunlight but not to the infrared light from the warmed surface of the earth. When greenhouse gases increase, more thermal energy is trapped in the atmosphere, and the temperature of the earth increases the light energy radiated into space until it again equals the light energy absorbed from the sun. 4B/H4 (SFAA) The atmosphere has mass, is bound to Earth by gravity, and exerts pressure which is greater near Earth's surface 	

and decreases with altitude. 1.2 (NOAA, 2008)

- The atmosphere, which is very thin relative to Earth's radius, varies vertically in layers which differ in composition, density, and temperature. The lowest 8-16 km of the atmosphere - the troposphere - contains most of Earth's weather systems. 1.3 (NOAA, 2008)

Common Student Misconceptions:

Although upper elementary students may identify air as existing even in static situations and recognize that it takes space, recognizing that air has weight may be challenging even for high-school students (Sere, M., 1985). Students of all ages (including college students) may believe that air exerts force or pressure only when it is moving and only downwards (Driver, R., Squires, A., Rushworth, P., Wood-Robinson, V., 1994). Only a few middle-school students use the idea of pressure differences between regions of the atmosphere to account for wind; instead they may account for winds in terms of visible moving objects or the movement of the earth (Driver, R., Squires, A., Rushworth, P., Wood-Robinson, V., 1994).

Students of all ages may confuse the ozone layer with the greenhouse effect, and may have a tendency to imagine that all environmentally friendly actions help to solve all environmental problems (for example, that the use of unleaded petrol reduces the risk of global warming) (Andersson, B., Wallin, A., 2000). Students have difficulty linking relevant elements of knowledge when explaining the greenhouse effect and may confuse the natural greenhouse effect with the enhancement of that effect (Andersson, B., Wallin, A., 2000).

Sample Integration of Science Practices and Core Content:

- What determines a planet's climate? Students seek answers and consensus by experimenting with physical and computer models, collecting and analyzing their own measurements, and conducting inter-comparisons with real world data from satellites and ground-based observations.
(NASA's [What Determines a Planet's Energy Budget?](http://icp.giss.nasa.gov/education/modules/eccm/) Viewed November 17, 2010 at: <http://icp.giss.nasa.gov/education/modules/eccm/>)
- Strange things have been happening in Earth's system. The atmosphere is losing ozone, and in the biosphere, skin cancer rates are up! One person in the United States dies each hour from these diseases, and more than 50% of new cancers in America are skin cancers.

In the hydrosphere, ultraviolet radiation is penetrating to depths never previously seen, while the lithosphere's volcanoes periodically spew sulfates and chlorine into the atmosphere. At the same time, in the realm of humans (the anthrosphere), manmade chemicals are continually being introduced into the other spheres. Are these events happening in isolation, or are they interrelated? The answer to this question is important to the future of the entire Earth system.

Your role is to evaluate the current status of the Montreal Protocol and determine if it adequately considers the interrelationship of Earth's spheres. To do this, you must investigate how an event in one sphere may have an effect in a second sphere, which may, in turn, affect a third sphere. You should determine if there is a need to revise the Protocol. In any event, you must be well prepared to defend your recommendations.

(UV Menace, Wheeling Jesuit University/NASA Classroom of the Future, Viewed October 22, 2010, <http://www.cotf.edu/ete/modules/ozone/uvmenace.html>)

Sample Assessment Item:

1. Recent studies indicate that ozone in the upper layers of Earth's atmosphere is being depleted. What effect does the depletion of ozone have, and how is this effect harmful to humans? (NAEP)
2. What makes a planet habitable?

Resources:

National Science Digital Library, Science Digital Literacy Maps

The Physical Setting: Weather and Climate: <http://strandmaps.nsdl.org/?id=SMS-MAP-1698>

Common Themes: Systems: <http://strandmaps.nsdl.org/?id=SMS-MAP-1594>

Science Curriculum Topic Study: Weather and Climate, p. 191

Systems, p. 271

Other Web Based Resources

National Science Foundation, National Oceanic and Atmospheric Administration, (2008). Essential Principles and Fundamental Concepts for Atmospheric Science Literacy. Published October 2008, retrieved August 2010. <http://eo.ucar.edu/asl/index.html>

5.4 Earth Systems Science: All students will understand that Earth operates as a set of complex, dynamic, and interconnected systems, and is a part of the all-encompassing system of the universe.

F. Climate and Weather: Earth's weather and climate systems are the result of complex interactions between land, ocean, ice, and atmosphere.

Essential Questions	Enduring Understandings
Is it possible for humans to influence a system as large as climate?	Climate is influenced by interactions of multiple physical, chemical and biological factors, including human actions.
Content Statements	Cumulative Progress Indicators
Climate is determined by energy transfer from the Sun at and near Earth's surface. This energy transfer is influenced by dynamic processes, such as cloud cover and Earth's rotation, as well as static conditions, such as proximity to mountain ranges and the ocean. Human activities, such as the burning of fossil fuels, also affect the global climate.	Explain how the climate in regions throughout the world is affected by seasonal weather patterns, as well as other factors, such as the addition of greenhouse gases to the atmosphere and proximity to mountain ranges and to the ocean. (5.4.12.F.2)

Instructional Focus:

- Climatic conditions result from latitude, altitude, and from the position of mountain ranges, oceans, and lakes. Dynamic processes such as cloud formation, ocean currents, and atmospheric circulation patterns influence climates as well. 4B/H5 (BSL)
- The earth's climates have changed in the past, are currently changing, and are expected to change in the future, primarily due to changes in the amount of light reaching places on the earth and the composition of the atmosphere. The burning of fossil fuels in the last century has increased the amount of greenhouse gases in the atmosphere, which has contributed to Earth's warming. 4B/H6 (BSL)
- Human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and intensive farming, have changed the earth's land, oceans, and atmosphere. Some of these changes have decreased the capacity of the environment to support some life forms. 4C/M7 (BSL)

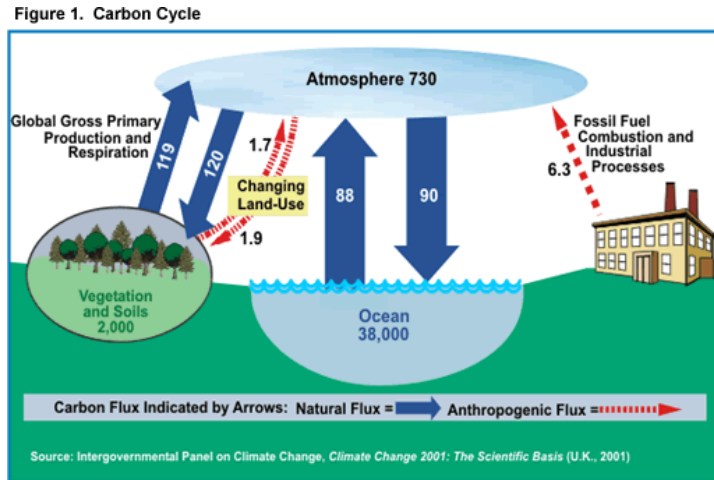
Sample Integration of Science Practices and Core Content:

Jim Anderson, a young computer programmer, has won the lottery. After taxes, he will be getting enough money to realize his life's dream: to buy and operate a wheat farm in Kansas. Ever since he was a boy visiting his grandparent's farm, Jim has dreamed of enjoying the outdoors and the satisfaction of planting and harvesting wheat.

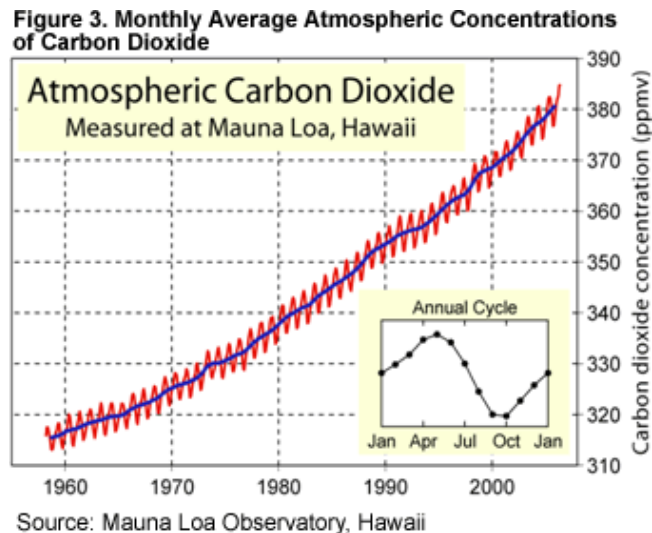
Jim and his wife have come to your firm, Earth Systems Science Environmental Research (ESSER) for technical advice. They want to make sure they are making a good investment. Using historical and predicted data provided in the "Remote Sensing" puzzle piece of this module, perform an Earth systems science analysis in order to determine how the yield of hard red winter wheat in Kansas will be affected by increased concentrations of atmospheric carbon dioxide as a result of its impacts on the four spheres. Provide recommendations or solutions as to whether or not Kansas wheat farmers will be able to maintain the current yields of this variety of wheat 50 years from now.

(Global Climate Change, Wheeling Jesuit University/NASA Classroom of the Future. Viewed October 21, 2010 at: <http://www.cotf.edu/ete/modules/climate/GCsituation.html>)

Sample Assessment Items:



- Based on Figure 1, what impact on the amount of CO_2 in the atmosphere would you expect to see if several hundred acres of forests were cut down to build houses?
 - The oceans would absorb more CO_2 to make up for the missing trees.
 - Primary productivity would change, but CO_2 levels would not increase.
 - Primary productivity would change and CO_2 levels would increase.
 - The water cycle would change.



- What generalization can you make about the amount of atmospheric carbon dioxide as represented by the graph in figure 3?
 - CO_2 levels have decreased more than 500 ppmv since 1960.
 - CO_2 levels have increased more than 500 ppmv since 1960.
 - CO_2 levels show an increasing trend since 1960, but vary with the seasons.

D. CO₂ levels show a decreasing trend since 1960 and show no change with the seasons.

Resources:

National Science Digital Library, Science Digital Literacy Maps

The Physical Setting: Weather and Climate: <http://strandmaps.nsdl.org/?id=SMS-MAP-1698>

Science Curriculum Topic Study: Weather and Climate, p. 191

Other Web Based Resources

National Science Foundation, National Oceanic and Atmospheric Administration, (2008). Essential Principles and Fundamental Concepts for Atmospheric Science Literacy. Published October 2008, retrieved August 2010.
<http://eo.ucar.edu/asl/index.html>

5.4 Earth Systems Science: All students will understand that Earth operates as a set of complex, dynamic, and interconnected systems, and is a part of the all-encompassing system of the universe.	
G. Biogeochemical Cycles: The biogeochemical cycles in the Earth systems include the flow of microscopic and macroscopic resources from one reservoir in the hydrosphere, geosphere, atmosphere, or biosphere to another, are driven by Earth's internal and external sources of energy, and are impacted by human activity.	
Essential Questions	Enduring Understandings
To what extent can human behaviors impact our planet's life support system (environment)?	Human activities have physical, chemical, and biological consequences for ecosystems; the magnitude of the impact depends in part on the sensitivity of the system to perturbation.
Content Statements	Cumulative Progress Indicators
Natural and human-made chemicals circulate with water in the hydrologic cycle.	Analyze and explain the sources and impact of a specific industry on a large body of water (e.g., Delaware or Chesapeake Bay). (5.4.12.G.1)
Instructional Focus:	
<ul style="list-style-type: none">The ocean is connected to major lakes, watersheds and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments and pollutants from watersheds to estuaries and to the ocean. <i>1.g</i> (NGS, NOAA, 2005)Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (point source, non-point source, and noise pollution) and physical modifications (changes to beaches, shores and rivers). <i>6.e</i> (NGS, NOAA, 2005)Water resources are essential for agriculture, manufacturing, energy production, and life. Earth scientists and engineers find and manage our fresh water resources, which are limited in supply. In many places, humans withdraw both surface water and groundwater faster than they are replenished. Once fresh water is contaminated, its quality is difficult to restore. <i>7.5</i> (NSF, 2009)Humans affect the quality, availability, and distribution of Earth's water through the modification of streams, lakes, and groundwater. Engineered structures such as canals, dams, and levees significantly alter water and sediment distribution. Pollution from sewage runoff, agricultural practices, and industrial processes reduce water quality. Overuse of water for electric power generation and agriculture reduces water availability for drinking. <i>9.4</i> (NSF, 2009)	
Common Student Misconceptions:	
Many students believe that anything natural is not pollution; biodegradable materials are not pollutants; solid waste in dumps is safe; and the human race is indestructible as a species. (Diver, 2006)	
Confusion between ozone layer depletion and the greenhouse effect is common. (Diver, 2006)	
Sample Integration of Science Practices and Core Content:	
<ul style="list-style-type: none">Investigate the importance and the location of your watershed. Use GIS technology to create an interactive map of their watershed, water quality, and ongoing efforts to improve or restore the watershed. Adapted from: <u>Know Your Watershed</u> found at: http://gc2000.rutgers.edu/GC2000/MODULES/ENVIRONMENT/watersheds.htm. Additional resources include: <u>Watershed Protection</u>, http://www.cwp.org/Students investigate water quality parameters to study the nature of, and the cyclical changes inherent in, the chemistry of estuarine water. Students study key water quality factors at several stations in a single reserve over time—current, daily, and yearly time scales. Students also compare water quality values over a yearly time scale in three different estuaries within NOAA's National Estuarine Research Reserve System (NERR) —South Slough NERR, Oregon; Delaware NERR; and Old Woman Creek NERR, Ohio. Then students take water quality measurements at a site near them and compare their data to the water in the three geographically diverse NERR estuarine environments. NOAA's Chemistry in an Estuary investigation found at:	

http://estuaries.gov/estuaries101/Doc/PDF/PS1_ChemistryEstuary.pdf

- Students model estuaries, artificially enriching both fresh and salt water samples with different amounts of nutrients and observing the growth of algae over a several weeks. They relate their results to the phenomenon of algae blooms in estuaries. They then analyze data for different sites at the Guana Tolomato Matanzas National Estuarine Research Reserve (GTMNERR) in Florida to discover the relationships between nitrogen, chlorophyll, and dissolved oxygen. Finally, they study how nutrients cycle through an estuary and suggest recommendations for reducing nutrient inputs to estuary waters. NOAA's [Nutrients in an Estuary](#) investigation found at:

http://estuaries.gov/estuaries101/Doc/PDF/LS2_NutrientsEstuary.pdf

Sample Assessment Item:

- You are shopping at the local lawn and garden store for lawn fertilizer. You notice that the maker of your favorite product has been reformulated to include less nitrogen. What is a possible impact of this reformulation beyond your property line?

Resources:

National Science Digital Library, Science Digital Literacy Maps

The Physical Setting: Use of Earth's Resources: <http://strandmaps.nsdli.org/?id=SMS-MAP-1699>

Science Curriculum Topic Study: Water in the Earth System, p. 190.

Human Impact on the Environment, p. 131

Pollution, p. 264

Other Web Based Resources:

NOAA's [Water Cycle Learning Object](#) found at:

<http://www.montereyinstitute.org/noaa/lesson07.html>

NOAA's [Water, Water Everywhere](#) where students estimate how much water they think can be found in various locations on the earth in all its states; solid, liquid, and gas. found at:

http://www.srh.noaa.gov/jetstream/atmos/ll_water.htm

Problem Based Learning Scenario titled [Water Quality](#), Wheeling Jesuit University/NASA Classroom of the Future, Viewed October 22, 2010,

<http://www.cotf.edu/ete/modules/waterq/wqsituation1.html>.

Problem Based Learning Scenario titled [Coral Reefs](#), Wheeling Jesuit University/NASA Classroom of the Future, Viewed October 22, 2010,

<http://www.cotf.edu/ete/modules/coralreef/CRsituation.html>.

National Geographic Society, National Oceanic and Atmospheric Administration, (2005). Ocean Literacy: The Essential Principles of Ocean Sciences. Published July 2005, retrieved August 2010. <http://oceanliteracy.wp.coexploration.org/>

National Science Foundation, (2009). Earth Science Literacy Principles. Published May 2009, retrieved August 2010.

<http://www.earthscienceliteracy.org/>

Content Statements	Cumulative Progress Indicators
Natural ecosystems provide an array of basic functions that affect humans. These functions include maintenance of the quality of the atmosphere, generation of soils, control of the hydrologic cycle, disposal of wastes, and recycling of nutrients.	Explain the unintended consequences of harvesting natural resources from an ecosystem. (5.4.12.G.2)
Instructional Focus: <ul style="list-style-type: none"> Human beings are part of the earth's ecosystems. Human activities can, deliberately or inadvertently, alter the 	

equilibrium in ecosystems. *5D/H3* (BSL)

- Although Earth has a great capacity to absorb and recycle materials naturally, ecosystems have only a finite capacity to withstand change without experiencing major ecological alterations that may also have adverse effects on human activities. *4B/H9* (BSL)
- The concept of Ecosystem Services is becoming popular as a way to encourage discussion about the dependence of humans on nature and what that means socially and economically. Ecosystem services are transformations of natural assets (soil, water, air, and living organisms) into products that are important to humans. Examples include: provision of clean air and water; maintenance of soil fertility; maintenance of liveable climates; pollination of crops and other vegetation; control of potential pests; provision of genetic resources; production of food and fiber; and provision of cultural, spiritual and intellectual experiences.
- The value of ecosystem services to humans comes from their role in supporting our lives, their cheapness, and our limited ability to replace them with human-engineered alternatives. (*Steven Cork, Ecosystem services: The many ways in which biodiversity sustains and fulfills human life.* viewed September 30, 2010
http://www.ecosystemsproject.org/html/publications/docs/Internet_forum_Nature_and_Society.pdf)

Sample Assessment Item:

You are considering investing in Cabot Oil & Gas Corporation who has been a leader in the extraction of natural gas from shale in the US. The ability to extract gas from shale — which can involve a process known as fracking — has been welcomed as an economic windfall by some communities and has been resisted in others because of residents' concerns about the potential harm to their drinking water. As part of your due diligence research, you found an article titled [When a Rig Moves In Next Door](#). After you read the article, craft a letter to your broker informing him of your decision to purchase the stock or not. In your letter, include your decision, the evidence that you found in the article that supports your decision, and a rationale for your decision.

(When a Rig Moves In Next Door, viewed on November 15, 2010 at:

<http://www.nytimes.com/2010/11/07/business/energy-environment/07frack.html>)

Sample Integration of Science Practices and Core Content:

The ancient forests of northwestern North America stretch from the redwoods of northern California to the Sitka spruce and Douglas fir of southeastern Alaska. How to utilize these natural resources has become a subject of intense debate among several competing interests.

Your group has been asked by the U.S.-Canadian Task Force on the Ancient Temperate Rainforests to study the dilemma and to submit recommendations for an international [policy](#) on the use of these forests of California, Oregon, Washington, British Columbia, and southeastern Alaska.

Where are the balance points among the competing demands and interests? Your rationale for each recommendation should be clearly stated and supported.

(Temperate Rainforest, Wheeling Jesuit University/NASA Classroom of the Future, Viewed October 22, 2010, <http://www.cotf.edu/ete/modules/temprain/temprain.html>)

Students use a “fish” model to simulate the tragedy of the commons, make predictions and generate conclusions about sustainable use practices. Tragedy of the Commons Activity,

<http://www.scienceteacherprogram.org/biology/szerlip03.html>

Resources:

National Science Digital Library, Science Digital Literacy Maps

The Physical Setting: Use of Earth's Resources: <http://strandmaps.nsdl.org/?id=SMS-MAP-1699>

Science Curriculum Topic Study: Human Impact on the Environment, p. 131

Content Statements	Cumulative Progress Indicators
Movement of matter through Earth's system is driven by Earth's internal and external sources of energy and results in changes in the physical and chemical properties of the matter.	Demonstrate, using models, how internal and external sources of energy drive the hydrologic, carbon, nitrogen, phosphorus, sulfur, and oxygen cycles. (5.4.12.G.3)
<p>Instructional Focus:</p> <ul style="list-style-type: none"> All Earth processes are the result of energy flowing and mass cycling within and between Earth's systems. This energy is derived from the sun and Earth's interior. The flowing energy and cycling matter cause chemical and physical changes in Earth's materials and living organisms. For example, large amounts of carbon continually cycle among systems of rock, water, air, organisms, and fossil fuels such as coal and oil. 3.2 (NSF, 2009) Earth exchanges mass and energy with the rest of the Solar System. Earth gains and loses energy through incoming solar radiation, heat loss to space, and gravitational forces from the sun, moon, and planets. Earth gains mass from the impacts of meteoroids and comets and loses mass by the escape of gases into space. 3.3 (NSF, 2009) The chemistry of ocean water is changed by absorption of carbon dioxide from the atmosphere. Increasing carbon dioxide levels in the atmosphere is causing ocean water to become more acidic, threatening the survival of shell-building marine species and the entire food web of which they are a part. 7.D (AAAS, NOAA, 2009) <p>Sample Integration of Science Practices and Core Content:</p> <p>Evaluate evidence contained in data sets and current models of Water Cycles, construct an argument regarding the claim that humans have serious problems with respect to how the water cycle functions. The Water Cycle and Global Warming, http://www.bioedonline.org/lessons/water-cycle.cfm</p> <p>Sample Assessment Item:</p> <ol style="list-style-type: none"> Describe how you could use common household materials to model two of the following cycles and how they interact. (Choose two: hydrologic, carbon, nitrogen, phosphorous, sulfur or oxygen). Create a podcast that explains the science behind the claim that each time we inhale, we literally breathe a few molecules of the same air that Einstein did. <p>Resources:</p> <p>National Science Digital Library, Science Digital Literacy Maps</p> <p>The Physical Setting: Changes in the Earth's Surface: http://strandmaps.nsdl.org/?id=SMS-MAP-0048</p> <p><i>Science Curriculum Topic Study:</i> Processes That Change The Surface of the Earth, p. 183</p>	
Content Statements	Cumulative Progress Indicators
Natural and human activities impact the cycling of matter and the flow of energy through ecosystems.	Compare over time the impact of human activity on the cycling of matter and energy through ecosystems. (5.4.12.G.4)
<p>Instructional Focus:</p> <ul style="list-style-type: none"> The transport and transformation of substances through the Earth system are known collectively as biogeochemical cycles. These include the hydrologic (water), nitrogen, carbon, and oxygen cycles. Human activities can, deliberating or inadvertently, alter the equilibrium of these cycles. <p>Sample Assessment Item:</p> <ol style="list-style-type: none"> The Hudson River receives large inputs of nutrients from the watershed and wastewater treatment plants. However, since the river has low water residence time, primary production remains low, and the visible effects of eutrophication are not noticeable. Use data to explore the changes that have taken place in nutrient loading over time in the Hudson River, and make recommendations about future improvements. (Viewed November 11, 	

2010 at: http://www.ecostudies.org/chp_waste_river.html Changing Hudson Project, Module 4 Pollution)

Sample Integration of Science Practices and Core Content:

Students model estuaries, artificially enriching both fresh and salt water samples with different amounts of nutrients and observing the growth of algae over a several weeks. They relate their results to the phenomenon of algae blooms in estuaries. They then analyze data for different sites at the Guana Tolomato Matanzas National Estuarine Research Reserve (GTMNERR) in Florida to discover the relationships between nitrogen, chlorophyll, and dissolved oxygen. Finally, they study how nutrients cycle through an estuary and suggest recommendations for reducing nutrient inputs to estuary waters. NOAA's [Nutrients in an Estuary](http://estuaries.gov/estuaries101/Doc/PDF/LS2_NutrientsEstuary.pdf) http://estuaries.gov/estuaries101/Doc/PDF/LS2_NutrientsEstuary.pdf

What are causes, impacts, and solutions to contaminated runoff? Engage students in NOAA's [Where's the point?](http://oceanservice.noaa.gov/education/lessons/wheres_the_point.html) found at: http://oceanservice.noaa.gov/education/lessons/wheres_the_point.html

How does a human-caused stress placed on the environment affect the life in a food web? Engage students in NOAA's [Chewin' in the Chesapeake](http://oceanservice.noaa.gov/education/pd/estuaries/estuarinebio/chewin_chesapeake_lesson.html) found at: http://oceanservice.noaa.gov/education/pd/estuaries/estuarinebio/chewin_chesapeake_lesson.html

How can resource managers and concerned public groups repair coastal resources damaged by human activity or natural events? Engage students in NOAA's [Fix It!](http://coralreef.noaa.gov/education/educators/resourcecd/lessonplans/resources/fix_it_lp.pdf) Found at: http://coralreef.noaa.gov/education/educators/resourcecd/lessonplans/resources/fix_it_lp.pdf

Explore the biomagnification of toxic chemical, mercury, through a simple marine food chain. In this simulation, the marine environment is contaminated with mercury. Although all animals are exposed to this toxic chemical, seabirds are more severely affected than other organisms. Engage students in NOAA's [Ocean Pollution](http://www.montereyinstitute.org/noaa/lesson13.html) found at: <http://www.montereyinstitute.org/noaa/lesson13.html>

Students explore the range of ocean characteristics preferred by coral reefs. Now that students are familiar with the environmental conditions in which corals survive and thrive, they are ready to explore the factors most likely to disrupt these conditions and threaten coral health and sustainability. Engage students in NOAA's [Exploring Factors that Impact Coral Health](http://serc.carleton.edu/earthlabs/corals/5.html) found at: <http://serc.carleton.edu/earthlabs/corals/5.html> (This website (serc.carleton.edu) is hosted by the [Science Education Resource Center](#) at [Carleton College](#).)

Resources:

National Science Digital Library, Science Digital Literacy Maps

The Living Environment: Interdependence of Life: <http://strandmaps.nsdl.org/?id=SMS-MAP-2122>

The Physical Setting: Use of Earth's Resources: <http://strandmaps.nsdl.org/?id=SMS-MAP-1699>

Science Curriculum Topic Study: Human Impact on the Environment, p. 131

Content Statements	Cumulative Progress Indicators
Human activities have changed Earth's land, oceans, and atmosphere, as well as its populations of plant and animal species.	Assess (using maps, local planning documents, and historical records) how the natural environment has changed since humans have inhabited the region. (5.4.12.G.5)
Instructional Focus: <ul style="list-style-type: none">The survival of human societies is dependent on Earth's resources. Overall, there are positive correlations between population, natural resource consumption and environmental degradation, although environmental policies and technology influence these relationships. This can be applied to the regional, national and global scales. (CB, 2009)	

- While urbanization may involve or provide a number of economic, social and environmental benefits, the global population demographic trend of increased urbanization that has been seen as more countries prepare to further industrialize may be associated with negative environmental and human health consequences. (CB, 2009)
- The size and rate of growth of the human population in any location are affected by economic, political, religious, technological and environmental factors. Some of these factors, in turn, are influenced by the size and rate of growth of the population. (BMSL, 7C/H1)
- Decisions to slow the depletion of energy resources can be made at many levels, from personal to national, and they always involve trade-offs involving economic costs and social values. (BMSL, 8C/H5)

Sample Assessment Item:

1. What are some reasons why approaches used by politicians and scientists to influence public policy differ? What are some unintended consequences for a watershed when one of these groups dominates decision making processes?
2. Using floodplain risk maps from your community, recommend possible sites for the following development; municipal park, retirement home village for senior citizens, apartment complex, public swimming pool, man-made levees, hospital, single family home, commuter parking lot, water-treatment plant, and communications tower. Justify your reasoning for the placements. If you think that some of these developments should be located within the limits of the map, explain why.

Sample Integration of Science Practices and Core Content:

Using historic thermal data images evaluate the effectiveness of rooftop gardens and increased green space to mitigate urban-heat-island-effects. Create a poster for a scientific “poster session” that includes: a. multiple representations of the data, b. your claim regarding the effectiveness of the rooftop garden, c. explanation of the reasoning for your claim citing your evidence,

Demonstrate understandings of how a disruption to a food chain can have a ripple effect through an ecosystem.

[Saved by a Shark](#) found at:

<http://www.nationalgeographic.com/xpeditions/lessons/07/g68/noaashark.html> (© 1998-2008 National Geographic Society)

Why is submerged aquatic vegetation (SAV) important in coastal ecosystems, and how can SAV be restored in areas where it has been depleted? NOAA’s [SAV Me!](#) found at:

http://oceanservice.noaa.gov/education/lessons/sav_me.html

A medicine man who makes his home in the tropical rainforest of the Amazon listens intently as huge trees crash to the forest's floor in the distance. He has been told that machines are being used to build roads into the forest and that many trees are being taken away on trucks. He wonders how long the plants and animals that are the sources for the potions he makes to heal and protect the members of this tribe will remain. As he looks at the ground, he notices a dart frog that provides the poisonous venom for the points of the darts and arrows the tribesmen use. By rubbing the points of the dart and arrows across the back of one of these frogs, hunters ensure a swift death to their prey.

At the same time, a medical researcher in the United States is engaged in a study to identify the medicinal properties of the dart frog's poison. Other researchers throughout the world are studying exotic vegetation that is found only in the tropical rainforests. One ethnobotanist has cataloged over 200 of these exotic plants along with their medical remedies. Soothing burns, easing childbirth, and healing infections are among some of the beneficial uses derived from these plants.

Is there a problem? Is the Amazon, the richest area of biodiversity in the world, threatened by human beings? Your group has been contacted by the Global Research Information Network (G.R.I.N.), an impartial panel composed of scientists and representatives from government, business, and industry. They want you to analyze the situation and make recommendations. They aren't sure what position to take concerning poison dart frogs and other species in the

Amazon.

(Tropical Poison Wheeling Jesuit University/NASA Classroom of the Future, Viewed October 22, 2010, <http://www.cotf.edu/ete/modules/troppois/troppois.html>)

Using [NJ-GeoWeb](#), create a stream-network map for your county; compare the locations of land uses that create pollutants to land uses that require uncontaminated water. Create a multimedia tour of your county identifying the locations of land uses that cause pollution, locations of land uses that require uncontaminated water, and natural geologic features that may help to reduce water contamination. The multimedia tour needs to identify what your community has done to prevent or remediate contamination of water resources.

Resources:

National Science Digital Library, Science Digital Literacy Maps

The Living Environment: Interdependence of Life: <http://strandmaps.nsdl.org/?id=SMS-MAP-2122>

The Physical Setting: Use of Earth's Resources: <http://strandmaps.nsdl.org/?id=SMS-MAP-1699>

Science Curriculum Topic Study: Human Impact on the Environment, p. 131

Content Statements	Cumulative Progress Indicators
Scientific, economic, and other data can assist in assessing environmental risks and benefits associated with societal activity.	Assess (using scientific, economic, and other data) the potential environmental impact of large-scale adoption of emerging technologies (e.g., wind farming, harnessing geothermal energy). (5.4.12.G.6)
<p>Instructional Focus:</p> <ul style="list-style-type: none">Decisions that affect the environment are not based on scientific analysis alone, but must also incorporate social and economic considerations. (CB, 2009)The benefits, costs and risks of decisions may not be evenly shared among all parties. In many cases, economically disadvantaged and/or minority groups have disproportionately suffered from these decisions, leading to concerns of <i>environmental justice</i>. (CB, 2009)Local, national and international laws, treaties and regulations have helped to manage environmental impacts. There are many examples of damaged ecosystems that have been successfully restored. (CB, 2009)People sometimes consider a local natural area or broader ecosystem to be “priceless” and hence refuse to put a dollar value on it. However, amid the conflicting interests of modern economic systems, the value of such ecosystems may then in practice be considered to be zero in economic analyses and public policy decisions. (CB, 2009)A newer approach used by a growing number of environmental scientists, ecologists and economists has been to try to assign dollar values, not to the ecosystem itself but to the services it provides. This can be determined by estimating the cost of providing the same service through human activity. In many cases, the value of these services is found to be very high, and thus maintenance of the functioning ecosystem becomes a high priority. (CB, 2009) <p>Sample Assessment Item:</p> <ol style="list-style-type: none">Using floodplain risk maps from your community, recommend possible sites for the following development; municipal park, retirement home village for senior citizens, apartment complex, public swimming pool, man-made levees, hospital, single family home, commuter parking lot, water-treatment plant, and communications tower. Justify your reasoning for the placements. If you think that some of these developments should be located within the limits of the map, explain why. <p>Sample Integration of Science Practices and Core Content:</p>	

Using historic thermal data images evaluate the effectiveness of rooftop gardens and increased green space to mitigate urban-heat-island-effects. Create a poster for a scientific “poster session” that includes:

- multiple representations of the data
- your claim regarding the effectiveness of the rooftop garden
- explanation of the reasoning for your claim citing your evidence

How and why should different perspectives be considered when deciding how to use and protect coastal resources?

Students engage in NOAA’s [I’ll Stay Here if it Kills me](http://oceanservice.noaa.gov/education/lessons/if_it_kills_me.html),
http://oceanservice.noaa.gov/education/lessons/if_it_kills_me.html

Human-induced nutrient loading of the world's oceans has been linked to increased and prolonged algae blooms, sometimes with potentially deadly consequences. In this investigation, students will create their own algal blooms, analyze satellite images of chlorophyll concentrations in the Sea of Cortés, and learn about two alarming consequences of excessive algae growth—dead zones and harmful algae blooms (HABs).

(<http://serc.carleton.edu/earthlabs/fisheries/7.html>). This website (serc.carleton.edu) is hosted by the [Science Education Resource Center](#) at [Carleton College](#).

Resources:

National Science Digital Library, Science Digital Literacy Maps

The Nature of Science: Evidence and Inquiry: <http://strandmaps.nsdl.org/?id=SMS-MAP-1200>

The Nature of Science: Avoiding Bias: <http://strandmaps.nsdl.org/?id=SMS-MAP-1224>

Habits of Mind: Detecting Flaws in Arguments: <http://strandmaps.nsdl.org/?id=SMS-MAP-2554>

The Mathematical World: Symbolic Representation: <http://strandmaps.nsdl.org/?id=SMS-MAP-1547>

The Mathematical World: Graphic Representation: <http://strandmaps.nsdl.org/?id=SMS-MAP-1538>

Science Curriculum Topic Study: Evidence and Explanation, p. 234

Identifying and Avoiding Bias, p. 237

Scientific and Logical Reasoning, p. 246

Summarizing and Representing Data, p. 249

Content Statements	Cumulative Progress Indicators
Earth is a system in which chemical elements exist in fixed amounts and move through the solid Earth, oceans, atmosphere, and living things as part of geochemical cycles.	Relate information to detailed models of the hydrologic, carbon, nitrogen, phosphorus, sulfur, and oxygen cycles, identifying major sources, sinks, fluxes, and residence times. (5.4.12.G.7)
Instructional Focus: <ul style="list-style-type: none"> Much of the complex behavior of the Earth system can be thought of as cycles involving physical, chemical and biological processes that transfer components among various storage locations over time. (CB, 2009). The inputs and outputs connecting such reservoirs, the changes in the physical state or chemical characteristics of the components, and the time scale of these processes can all be recognized and quantified. (CB, 2009). Biogeochemical cycles, such as the water cycle and carbon cycle, are driven and sustained by solar and/or geothermal energy, which is transferred, utilized and lost as an integral aspect of the cycles. (CB, 2009). 	
Common Student Misconceptions: These are similar to those identified above regarding carbon cycling.	

Sample Assessment Item:

1. In many textbooks, the water cycle and carbon cycle are illustrated with neat lines suggesting the movement of material though a cycle in a neat orderly progression. Explain, in terms of residence times why the idealized illustrations may lead to incorrect understandings of one of these biogeochemical systems.

Resources:

National Science Digital Library, Science Digital Literacy Maps

The Physical Setting: Conservation of Matter: <http://strandmaps.nsdlib.org/?id=SMS-MAP-1332>

Science Curriculum Topic Study: Water Cycle, p. 189

Cycling of Matter in Ecosystems, p. 124

5.1 Science Practices: Science is both a body of knowledge and an evidence-based, model-building enterprise that continually extends, refines, and revises knowledge. The four Science Practices strands encompass the knowledge and reasoning skills that students must acquire to be proficient in science.	
A. Understand Scientific Explanations: Students understand core concepts and principles of science and use measurement and observation tools to assist in categorizing, representing, and interpreting the natural and designed world.	
Essential Question	Enduring Understanding
How do we build and refine models that describe and explain the natural and designed world?	Measurement and observation tools are used to categorize, represent and interpret the natural world.
Content Statement	Cumulative Progress Indicator
Mathematical, physical, and computational tools are used to search for and explain core scientific concepts and principles.	Refine interrelationships among concepts and patterns of evidence found in different central scientific explanations. (5.1.12.A.1)
Instructional Focus: <ul style="list-style-type: none"> Learning facts, concepts, principles, theories and models; then Developing an understanding of the relationships among facts, concepts, principles, theories and models; then Using these relationships to understand and interpret phenomena in the natural world Misconceptions: <p>Students of all ages find it difficult to distinguish between a theory and the evidence for it, or between description of evidence and interpretation of evidence. Some research suggests students can start understanding the distinction between theory and evidence after adequate instruction, as early as middle school (Roseberry, A., Warren, B., Conant, F., 1992).</p> <p>When asked to use evidence to judge a theory, students of all ages may make only theory-based responses with no reference made to the presented evidence. Sometimes this appears to be because the available evidence conflicts with the students' beliefs (Kuhn, 1988).</p> <p>Most high-school students will accept arguments based on inadequate sample size, accept causality from contiguous events, and accept conclusions based on statistically insignificant differences (Jungwirth, 1987, 1990, 1992). More students can recognize these inadequacies in arguments after prompting. For example, after being told that the conclusions drawn from the data were invalid and asked to state why (Jungwirth, 1992).</p> Resources: <p>National Science Digital Library, Science Digital Literacy Maps</p> <p>The Nature of Science: Scientific Theories: http://strandmaps.nsdl.org/?id=SMS-MAP-1216</p> <p>The Nature of Science: Evidence and Reasoning: http://strandmaps.nsdl.org/?id=SMS-MAP-1200</p> <p><i>Taking Science to School:</i> Knowledge and Understanding of the Natural World, pp. 93-120</p>	
Content Statement	Cumulative Progress Indicator
Interpretation and manipulation of evidence-based models are used to build and critique arguments/explanations.	Develop and use mathematical, physical, and computational tools to build evidence-based models and to pose theories. (5.1.12.A.2)
Instructional Focus: <ul style="list-style-type: none"> Using tools, evidence and data to observe, measure, and explain phenomena in the natural world 	

- Developing evidence-based models based on the relationships among fundamental concepts and principals
- Constructing and refining explanations, arguments or models of the natural world through the use of quantitative and qualitative evidence and data

Connections to the [Common Core State Standards for Mathematics](#):

- Summarize categorical data for two categories in two-way frequency tables. Interpret relative frequencies in the context of the data (including joint, marginal, and conditional relative frequencies). Recognize possible associations and trends in the data. **(S.10.5)**
- Interpret the slope (rate of change) and the intercept (constant term) of a linear model in the context of the data. **(S.10.7)**
- Compute (using technology) and interpret the correlation coefficient of a linear fit. **(S.10.8)**
- Use data from a randomized experiment to compare two treatments; use simulations to decide if differences between parameters are significant. **(S.IC.5)**

Misconceptions:

Students who can use measuring instruments and procedures when asked to do so often do not use this ability while performing an investigation. Typically a student asked to undertake an investigation and given a set of equipment that includes measuring instruments will make a qualitative comparison even though she might be competent to use the instruments in a different context (Black, P., 1990). It appears students often know how to take measurements but not what measurements to make or when (AAAS, 2007).

Prior to instruction, or after traditional instruction, many middle- and high-school students continue to focus on perceptual rather than functional similarities between models and their referents, and think of models predominantly as small copies of real objects. Consequently, students often interpret models they encounter in school science too literally and unshared attributes between models and their referents are a cause of misunderstanding. Some middle- and high-school students view visual representations such as maps or diagrams as models, but only a few students view representations of ideas or abstract entities as models.

Many middle- and high-school students think that models are useful for visualizing ideas and for communication purposes. Only a few students think that models are useful in developing and testing ideas and that the usefulness of a model can be tested by comparing its implications to actual observations.

Middle-school and high-school students accept the idea that scientists can have more than one model for the same thing. However, having multiple models may mean for them that one could have literally a different view of the same entity, or that one could emphasize different aspects of the same entity -- omitting or highlighting certain things to provide greater clarity. Students are rarely aware that there could be different models to explain something or to evaluate alternative hypotheses. They find multiple model use in school science confusing are rarely use multiple models to think about phenomena; even if they do, the idea that one model is "right" and "real" persists. Students may know that models can be changed, but changing a model for them means (typical of high-school students) adding new information or (typical of middle-school students) replacing a part that was made wrong.

Developing and evaluating models combined with explicit instruction and reflection about the nature of models and modeling for an extended period of time can be effective in helping middle-school students make progress toward the following ideas: Models are not necessarily physical objects but could be conceptual representations that help scientists to predict and explain; there can be multiple models for the same phenomenon; and models are useful in visualization,

predicting phenomena, and conducting investigations that are not otherwise possible. The ideas that scientists revise their models in light of new insights or new data and that not all models are of equal value may be harder to develop.

Resources:

National Science Digital Library, Science Digital Literacy Maps

Habits of Mind: Using Tools: <http://strandmaps.nsdl.org/?id=SMS-MAP-2507>

Common Themes: Models: <http://strandmaps.nsdl.org/?id=SMS-MAP-2408>

Comparison of the Project 2061 [Benchmarks for Science Literacy and the National Council of Teachers of Mathematics Curriculum and Evaluation Standards for School Mathematics](http://www.project2061.org/publications/rsl/online/COMPARE/NCTM/N2B/M2BTOC.HTM) was commissioned by Project 2061. The intent is to indicate, for each NCTM standard, the benchmarks that are *most nearly related to it*. We hope that educators interested in mathematical literacy and meaningful integration will find the comparison interesting and perhaps useful in thinking through their own learning goals.
[Literacyhttp://www.project2061.org/publications/rsl/online/COMPARE/NCTM/N2B/M2BTOC.HTM](http://www.project2061.org/publications/rsl/online/COMPARE/NCTM/N2B/M2BTOC.HTM)

Science Curriculum Topic Study: Observation, Measurement, and Tools, p. 242

Evidence and Explanation, p. 234

Models, p. 269

Content Statement	Cumulative Progress Indicator
Revisions of predictions and explanations are based on systematic observations, accurate measurements, and structured data/evidence.	Use scientific principles and theories to build and refine standards for data collection, posing controls, and presenting evidence. (5.1.12.A.3)

Instructional Focus:

- Understanding that data differs in quality and strength of explanatory power based on experimental design
- Evaluating strength of scientific arguments based on the quality of the data and evidence presented
- Critiquing scientific arguments by considering the selected experimental design and method of data analysis

Resources:

National Science Digital Library, Science Digital Literacy Maps

Habits of Mind: Detecting Flaws in Arguments: <http://strandmaps.nsdl.org/?id=SMS-MAP-2554>

Habits of Mind: Values in Science: <http://strandmaps.nsdl.org/?id=SMS-MAP-2469>

The Mathematical World: Reasoning: <http://strandmaps.nsdl.org/?id=SMS-MAP-2300>

Science Curriculum Topic Study: Experimental Design, p. 235

Identifying and Avoiding Bias, p. 237

5.1 Science Practices: Science is both a body of knowledge and an evidence-based, model-building enterprise that continually extends, refines, and revises knowledge. The four Science Practices strands encompass the knowledge and reasoning skills that students must acquire to be proficient in science.

B. Generate Scientific Evidence Through Active Investigations: Students master the conceptual, mathematical, physical, and computational tools that need to be applied when constructing and evaluating claims.

Essential Question	Enduring Understanding
What constitutes useful scientific evidence?	Evidence is used for building, refining, and/or critiquing scientific explanations.
Content Statement	Cumulative Progress Indicator
Logically designed investigations are needed in order to generate the evidence required to build and refine models and explanations.	Design investigations, collect evidence, analyze data, and evaluate evidence to determine measures of central tendencies, causal/correlational relationships, and anomalous data. (5.1.12.B.1)

Instructional Focus:

- Asking a question and deciding what to measure in order to answer the question
- Developing strategies for obtaining measurements, then systematically collecting data
- Structuring the gathered data, then interpreting and evaluating the data
- Using the empirical results to determine causal/correlational relationships

Connections to the [Common Core State Standards for Mathematics](#):

- Recognize that a measure of center for a numerical data set summarizes all of its values with a single number, while a measure of variation describes how its values vary with a single number. **(6.SP.3)**
- Summarize numerical data sets in relation to their context, such as by:
 - a. Reporting the number of observations.
 - b. Describing the nature of the attribute under investigation, including how it was measured and its units of measurement.
 - c. Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.
 - d. Relating the choice of measures of center and variability to the shape of the data distribution and the context in which the data were gathered. **(6.SP.5)**
- Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association. **(8.SP.1)**
- Compute (using technology) and interpret the correlation coefficient of a linear fit. **(S.ID.8)**
- Distinguish between correlation and causation. **(S.ID.9)**

Misconceptions:

When engaged in experimentation, students have difficulty interpreting covariation and noncovariation evidence (Kuhn, 1998). For example, students tend to make a causal inference based on a single concurrence of antecedent and outcome or have difficulty understanding the distinction between a variable having no effect and a variable having an opposite effect.

Most high-school students will accept arguments based on inadequate sample size, accept causality from contiguous events, and accept conclusions based on statistically insignificant differences (Jungwirth, E., Dreyfus, A., 1987, 1990, 1992). More students can recognize these inadequacies in arguments after prompting. For example, after being told that the conclusions drawn from the data were invalid and asked to state why (Jungwirth, E., Dreyfus, A., 1992).

Students of all ages show a tendency to uncritically infer cause from correlation (Kuhn, D., Amsel, E., O'Loughlin, M., 1988). Some students think even a single co-occurrence of antecedent and outcome is always sufficient to infer causality. Rarely do middle-school students realize the indeterminacy of single instances, although high-school students may readily realize it. Despite that, as covariant data accumulate, even high school students will infer a causal relation based on correlations. Further, students of all ages will make a causal inference even when no variation occurs in one of the variables. For example, if students are told that light-colored balls are used successfully in a game, they seem willing to infer that the color of the balls will make some difference in the outcome even without any evidence about dark colored balls (Kuhn, D., Amsel, E., O'Loughlin, M., 1988).

Faced with no correlation of antecedent and outcome, 6th-graders only rarely conclude that the variable has no effect on the outcome. Ninth-graders draw such conclusions more often. A basic problem appears to be understanding the distinction between a variable making no difference and a variable that is correlated with the outcome in the opposite way that the students initially conceived.

Resources:

National Science Digital Library, Science Digital Literacy Maps

Habits of Mind: Using Tools and Devices: <http://strandmaps.nsdl.org/?id=SMS-MAP-2507>

The Nature of Science: Scientific Investigations: <http://strandmaps.nsdl.org/?id=SMS-MAP-1207>

The Mathematical World: Correlation: <http://strandmaps.nsdl.org/?id=SMS-MAP-1579>

Comparison of the Project 2061 [Benchmarks for Science Literacy](#) and the National Council of Teachers of Mathematics [Curriculum and Evaluation Standards for School Mathematics](#) was commissioned by Project 2061. The intent is to indicate, for each NCTM standard, the benchmarks that are *most nearly related to it*. We hope that educators interested in mathematical literacy and meaningful integration will find the comparison interesting and perhaps useful in thinking through their own learning goals.

[Literacyhttp://www.project2061.org/publications/rsl/online/COMPARE/NCTM/N2B/M2BTOC.HTM](http://www.project2061.org/publications/rsl/online/COMPARE/NCTM/N2B/M2BTOC.HTM)

Taking Science to School: Generating and Evaluating Scientific Evidence and Explanations, pp. 129- 160

Science Curriculum Topic Study: Science as Inquiry, p. 245

Data Collection and Analysis, p. 233

Controlling Variables, p. 231

Correlation, p. 232

Content Statement	Cumulative Progress Indicator
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Mathematical tools and technology are used to gather, analyze, and communicate results.	Build, refine, and represent evidence-based models using mathematical, physical, and computational tools. (5.1.12.B.2)
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Instructional Focus:

- Using mathematics in the collection and treatment of data and in the reasoning used to develop concepts, laws and theories
- Using tools of data analysis to organize data and formulate hypotheses for further testing
- Using existing mathematical, physical, and computational models to analyze and communicate findings

Connections to the [Common Core State Standards for Mathematics](#):

- Develop a probability model and use it to find probabilities of events. Compare probabilities from a model to observed frequencies; if the agreement is not good, explain possible sources of the discrepancy.
 - a. Develop a uniform probability model by assigning equal probability to all outcomes, and use the model to determine probabilities of events. *For example, if a student is selected at random from a class, find the probability that Jane will be selected and the probability that a girl will be selected.*
 - b. Develop a probability model (which may not be uniform) by observing frequencies in data generated from a chance process. *For example, find the approximate probability that a spinning penny will land heads up or that a tossed paper cup will land open-end down. Do the outcomes for the spinning penny appear to be equally likely based on the observed frequencies? (7.SP.7)*
- Construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function from a description of a relationship or from two (x, y) values, including reading these from a table or from a graph. Interpret the rate of change and initial value of a linear function in terms of the situation it models, and in terms of its graph or a table of values. (8.F.4)
- Know that straight lines are widely used to model relationships between two quantitative variables. For scatter plots that suggest a linear association, informally fit a straight line, and informally assess the model fit by judging the closeness of the data points to the line. (8.SP.2)
- Define appropriate quantities for the purpose of descriptive modeling. (N.Q.2)
- (+) Recognize vector quantities as having both magnitude and direction. Represent vector quantities by directed line segments, and use appropriate symbols for vectors and their magnitudes (e.g., \mathbf{v} , $|\mathbf{v}|$, $\|\mathbf{v}\|$, v). (N.VM.1)
- Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or nonviable options in a modeling context. *For example, represent inequalities describing nutritional and cost constraints on combinations of different foods. (A.CED.3)*
- For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. *Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums;*

symmetries; end behavior; and periodicity. (F.IF.4)

- Write arithmetic and geometric sequences both recursively and with an explicit formula, use them to model situations, and translate between the two forms. (F.BF.2)

Misconceptions:

Students have difficulty understanding how symbols are used in algebra. They are often unaware of the arbitrariness of the letters chosen to represent variables in equations. Middle-school and high-school students may regard the letters as shorthand for single objects, or as specific but unknown numbers, or as generalized numbers before they understand them as representations of variables. Students' lack of awareness of the arbitrariness of the letters chosen to represent variables in equations tends to persist even after instruction in algebra. Student difficulty in understanding how symbols are used in algebra is evident even in college students.

Students tend to look for or accept evidence that is consistent with their prior beliefs and either distort or fail to generate evidence that is inconsistent with these beliefs. These deficiencies tend to mitigate over time and with experience (Schauble, L., 1990).

Resources:

National Science Digital Library, Science Digital Literacy Maps

Habits of Mind: Using Tools and Devices: <http://strandmaps.nsdl.org/?id=SMS-MAP-2507>

Common Themes, Models: <http://strandmaps.nsdl.org/?id=SMS-MAP-2408>

The Nature of Mathematics: Mathematical Models: <http://strandmaps.nsdl.org/?id=SMS-MAP-1240>

Comparison of the Project 2061 [Benchmarks for Science Literacy](http://www.project2061.org/publications/rsl/online/COMPARE/NCTM/N2B/M2BTOC.HTM) and the National Council of Teachers of Mathematics [Curriculum and Evaluation Standards for School Mathematics](http://www.nctm.org/publications/standards/standards-for-mathematical-practice.aspx) was commissioned by Project 2061. The intent is to indicate, for each NCTM standard, the benchmarks that are *most nearly related to it*. We hope that educators interested in mathematical literacy and meaningful integration will find the comparison interesting and perhaps useful in thinking through their own learning goals.

[Literacyhttp://www.project2061.org/publications/rsl/online/COMPARE/NCTM/N2B/M2BTOC.HTM](http://www.project2061.org/publications/rsl/online/COMPARE/NCTM/N2B/M2BTOC.HTM)

Science Curriculum Topic Study: Data Collection and Analysis, p. 233

Graphs and Graphing, p. 236

Mathematical Modeling, p. 239

Observation, Measurement, and Tools, p. 242

Content Statement	Cumulative Progress Indicator
Empirical evidence is used to construct and defend arguments.	Revise predictions and explanations using evidence, and connect explanations/arguments to established scientific knowledge, models, and theories. (5.1.12.B.3)
Instructional Focus: <ul style="list-style-type: none">Making claims based on the available evidence	

- Explaining the reasoning, citing evidence, behind a proposed claim
- Connecting the claim to established concepts and principles

Misconceptions:

One common misconception is the idea of representativeness, according to which an event is believed to be probable to the extent that it is "typical." For example, many people believe that after a run of heads in coin tossing, tails should be more likely to come up. Another common error is estimating the likelihood of events based on how easily instances of it can be brought to mind (AAAS, 2001).

Resources:

National Science Digital Library, Science Digital Literacy Maps

The Nature of Science: Scientific Theories: <http://strandmaps.nsdl.org/?id=SMS-MAP-1216>

The Mathematical World: Statistical Reasoning: <http://strandmaps.nsdl.org/?id=SMS-MAP-1586>

Science Curriculum Topic Study: Evidence and Explanation, p. 234

Content Statement	Cumulative Progress Indicator
Scientific reasoning is used to evaluate and interpret data patterns and scientific conclusions.	Develop quality controls to examine data sets and to examine evidence as a means of generating and reviewing explanations. (5.1.12.B.4)

Instructional Focus:

- Analyzing experimental data sets using measures of central tendency
- Representing and describing mathematical relationships among variables using graphs and tables
- Using mathematical tools to construct and evaluate claims

Misconceptions:

Most high-school students will accept arguments based on inadequate sample size, accept causality from contiguous events, and accept conclusions based on statistically insignificant differences (Jungwirth, E., Dreyfus, A., 1987, 1990, 1992). More students can recognize these inadequacies in arguments after prompting (for example, after being told that the conclusions drawn from the data were invalid and asked to state why).

Resources:

National Science Digital Library, Science Digital Literacy Maps

The Nature of Science: Evidence and Reasoning: <http://strandmaps.nsdl.org/?id=SMS-MAP-1200>

The Mathematical World: Averages and Comparisons: <http://strandmaps.nsdl.org/?id=SMS-MAP-1571>

The Mathematical World: Correlation: <http://strandmaps.nsdl.org/?id=SMS-MAP-1579>

Science Curriculum Topic Study: Correlation, p. 232

Scientific and Logical Reasoning, p. 246

Mathematics in Science and Technology, p. 241

5.1 Science Practices: Science is both a body of knowledge and an evidence-based, model-building enterprise that continually extends, refines, and revises knowledge. The four Science Practices strands encompass the knowledge and reasoning skills that students must acquire to be proficient in science.

C. Reflect on Scientific Knowledge: Scientific knowledge builds on itself over time.

Essential Question	Enduring Understanding
How is scientific knowledge constructed?	Scientific knowledge builds upon itself over time.
Content Statement	Cumulative Progress Indicator
Refinement of understandings, explanations, and models occurs as new evidence is incorporated.	Reflect on and revise understandings as new evidence emerges. (5.1.12.C.1)

Instructional Focus:

- Reflecting on the status of one's own thinking and learning (i.e. uncovering how a student knows what they know and why)
- Thinking about themselves as science learners and developing an identity as someone who knows about, uses, and sometimes contributes to science.
- Understanding that scientific knowledge can be revised as new evidence emerges

Resources:

National Science Digital Library, Science Digital Literacy Maps

The nature of Science: Scientific Investigations: <http://strandmaps.nsdl.org/?id=SMS-MAP-1207>

The Nature of Science: Scientific Theories: <http://strandmaps.nsdl.org/?id=SMS-MAP-1216>

Taking Science to School: Understanding How Scientific Knowledge is Constructed, pp. 168-182

Science Curriculum Topic Study: The Nature of Scientific Thought and Development, p. 241

Science as a Human Endeavor, p. 244

Content Statement	Cumulative Progress Indicator
Data and refined models are used to revise predictions and explanations.	Use data representations and new models to revise predictions and explanations. (5.1.12.C.2)

Instructional Focus:

- Recognizing that predictions or explanations can be revised on the basis of seeing new data and evidence
- Using data and evidence to modify and extend investigations
- Understanding that explanations are increasingly valuable as they account for the available evidence more completely

Connections to the [Common Core State Standards for Mathematics](#):

- Write a function that describes a relationship between two quantities.
 - Determine an explicit expression, a recursive process, or steps for calculation from a context.
 - Combine standard function types using arithmetic operations. *For example, build a function that models the temperature of a cooling body by adding a constant function to a decaying exponential, and relate these functions to the model.*
 - (+) Compose functions. *For example, if $T(y)$ is the temperature in the atmosphere as a*

function of height, and $h(t)$ is the height of a weather balloon as a function of time, then $T(h(t))$ is the temperature at the location of the weather balloon as a function of time. **(F.BF.1)**

- Represent data on two quantitative variables on a scatter plot, and describe how the variables are related.
 - a. Fit a function to the data; use functions fitted to data to solve problems in the context of the data. *Use given functions or choose a function suggested by the context. Emphasize linear, quadratic, and exponential models.*
 - b. Informally assess the fit of a function by plotting and analyzing residuals.
 - c. Fit a linear function for a scatter plot that suggests a linear association. **(S.ID.6)**
- Decide if a specified model is consistent with results from a given data-generating process, e.g., using simulation. *For example, a model says a spinning coin falls heads up with probability 0.5. Would a result of 5 tails in a row cause you to question the model?* **(S.IC.2)**
- Use data from a sample survey to estimate a population mean or proportion; develop a margin of error through the use of simulation models for random sampling. **(S.IC.4)**
- (+) Develop a probability distribution for a random variable defined for a sample space in which theoretical probabilities can be calculated; find the expected value. *For example, find the theoretical probability distribution for the number of correct answers obtained by guessing on all five questions of a multiple-choice test where each question has four choices, and find the expected grade under various grading schemes.* **(S.MD.3)**
- (+) Develop a probability distribution for a random variable defined for a sample space in which probabilities are assigned empirically; find the expected value. *For example, find a current data distribution on the number of TV sets per household in the United States, and calculate the expected number of sets per household. How many TV sets would you expect to find in 100 randomly selected households?* **(S.MD.4)**

Resources:

National Science Digital Library, Science Digital Literacy Maps

The Nature of Science: Scientific Investigations: <http://strandmaps.nsdl.org/?id=SMS-MAP-1207>

The Nature of Science: Scientific Theories: <http://strandmaps.nsdl.org/?id=SMS-MAP-1216>

Comparison of the Project 2061 [Benchmarks for Science Literacy and the National Council of Teachers of Mathematics Curriculum and Evaluation Standards for School Mathematics](#) was commissioned by Project 2061. The intent is to indicate, for each NCTM standard, the benchmarks that are *most nearly related to it*. We hope that educators interested in mathematical literacy and meaningful integration will find the comparison interesting and perhaps useful in thinking through their own learning goals.

[Literacyhttp://www.project2061.org/publications/rsl/online/COMPARE/NCTM/N2B/M2BTOC.HTM](http://www.project2061.org/publications/rsl/online/COMPARE/NCTM/N2B/M2BTOC.HTM)

Taking Science to School: Understanding How Scientific Knowledge is Constructed, pp. 168-182

Science Curriculum Topic Study: The Nature of Scientific Thought and Development, p. 241
Science as a Human Endeavor, p. 244

Content Statement	Cumulative Progress Indicator
Science is a practice in which an established body of knowledge is continually revised, refined, and extended as new evidence emerges.	Consider alternative theories to interpret and evaluate evidence-based arguments. (5.1.12.C.3)

Instructional Focus:

- Understanding that there might be multiple interpretations of the same phenomena
- Stepping back from evidence and explanations to consider whether another interpretation of a particular finding is plausible with respect to existing scientific evidence
- Considering alternative perspectives worthy of further investigations

See Mathematical Connections for 5.1.12.C.2

Misconceptions:

Some students of all ages believe science mainly invents things or solves practical problems rather than exploring and understanding the world. Some high-school students believe that moral values and personal motives do not influence a scientist's contributions to the public debate about science and technology and think that scientists are more capable than others to decide those issues.

Resources:

National Science Digital Library, Science Digital Literacy Maps

The Nature of Science: Scientific Investigations: <http://strandmaps.nsdl.org/?id=SMS-MAP-1207>

The Nature of Science: Scientific Theories: <http://strandmaps.nsdl.org/?id=SMS-MAP-1216>

Taking Science to School: Understanding How Scientific Knowledge is Constructed, pp. 168-182

Science Curriculum Topic Study: The Nature of Scientific Thought and Development, p. 241
Science as a Human Endeavor, p. 24

5.1 Science Practices: Science is both a body of knowledge and an evidence-based, model-building enterprise that continually extends, refines, and revises knowledge. The four Science Practices strands encompass the knowledge and reasoning skills that students must acquire to be proficient in science.	
D. Participate Productively in Science: The growth of scientific knowledge involves critique and communication, which are social practices that are governed by a core set of values and norms.	
Essential Question	Enduring Understanding
How does scientific knowledge benefit – deepen and broaden - from scientists sharing and debating ideas and information with peers?	The growth of scientific knowledge involves critique and communication - social practices that are governed by a core set of values and norms.
Content Statement	Cumulative Progress Indicator
Science involves practicing productive social interactions with peers, such as partner talk, whole-group discussions, and small-group work.	Engage in multiple forms of discussion in order to process, make sense of, and learn from others’ ideas, observations, and experiences. (5.1.12.D.1)
Instructional Focus: <ul style="list-style-type: none"> • Seeing oneself as an effective participant and contributor in science • Interacting with others to test new ideas, soliciting and providing feedback, articulating and evaluating emerging explanations, developing shared representations and models, and reaching consensus • Developing a sense of appropriate trust and skepticism when evaluating others’ claims, evidence and reasoning <div style="border: 1px solid red; padding: 10px; margin: 10px 0;"> <p>Connections to the Common Core State Standards for English Language Arts Standards: Students must learn to read, write, speak, listen, and use language effectively in science. The Common Core State Standards specify the literacy skills and understandings required for college and career readiness in multiple disciplines, including science. The CCST can be found at: http://www.corestandards.org/the-standards/english-language-arts-standards</p> </div> <p>Resources: National Science Digital Library, Science Digital Literacy Maps Habits of Mind: Communication Skills: http://strandmaps.nsdl.org/?id=SMS-MAP-2531 The Nature of Science: Avoiding Bias: http://strandmaps.nsdl.org/?id=SMS-MAP-1224</p> <p><i>Taking Science to School:</i> Participation in Scientific Practices and Discourse, pp. 186-203</p> <p><i>Science Curriculum Topic Study:</i> Science as a Human Endeavor, p. 244 Communication in Science, p. 230</p>	
Content Statement	Cumulative Progress Indicator
Science involves using language, both oral and written, as a tool for making thinking public.	Represent ideas using literal representations, such as graphs, tables, journals, concept maps, and diagrams. (5.1.12.D.2)

Instructional Focus:

- Constructing literal representations from empirical evidence and observations
- Presenting and defending a scientific argument using literal representations
- Evaluating others' literal representations for consistency with their claims, evidence and reasoning
- Moving fluently between representations such as graphs, data, equations, diagrams and verbal explanations

Connections to the [Common Core State Standards for Mathematics](#):

- Display numerical data in plots on a number line, including dot plots, histograms, and box plots. **(6.SP.4)**
- Summarize numerical data sets in relation to their context, such as by:
 - a. Reporting the number of observations.
 - b. Describing the nature of the attribute under investigation, including how it was measured and its units of measurement.
 - c. Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.
 - d. Relating the choice of measures of center and variability to the shape of the data distribution and the context in which the data were gathered. **(6.SP.5)**
- Informally assess the degree of visual overlap of two numerical data distributions with similar variabilities, measuring the difference between the centers by expressing it as a multiple of a measure of variability. *For example, the mean height of players on the basketball team is 10 cm greater than the mean height of players on the soccer team, about twice the variability (mean absolute deviation) on either team; on a dot plot, the separation between the two distributions of heights is noticeable.* **(7.SP.3)**
- Use measures of center and measures of variability for numerical data from random samples to draw informal comparative inferences about two populations. *For example, decide whether the words in a chapter of a seventh-grade science book are generally longer than the words in a chapter of a fourth-grade science book.* **(7.SP.4)**
- Understand that patterns of association can also be seen in bivariate categorical data by displaying frequencies and relative frequencies in a two-way table. Construct and interpret a two-way table summarizing data on two categorical variables collected from the same subjects. Use relative frequencies calculated for rows or columns to describe possible association between the two variables. *For example, collect data from students in your class on whether or not they have a curfew on school nights and whether or not they have assigned chores at home. Is there evidence that those who have a curfew also tend to have chores?* **(8.SP.1)**
- For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. *Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; and periodicity.* **(F.IF.4)**

Resources:

National Science Digital Library, Science Digital Literacy Maps

Habits of Mind: Communication Skills: <http://strandmaps.nsdl.org/?id=SMS-MAP-2531>

The Mathematical World: Mathematical Representation: <http://strandmaps.nsdl.org/?id=SMS-MAP-1547>

Comparison of the Project 2061 [Benchmarks for Science Literacy and the National Council of Teachers of Mathematics Curriculum and Evaluation Standards for School Mathematics](http://www.project2061.org/publications/rsl/online/COMPARE/NCTM/N2B/M2BTOC.HTM) was commissioned by Project 2061. The intent is to indicate, for each NCTM standard, the benchmarks that are *most nearly related to it*. We hope that educators interested in mathematical literacy and meaningful integration will find the comparison interesting and perhaps useful in thinking through their own learning goals.

[Literacyhttp://www.project2061.org/publications/rsl/online/COMPARE/NCTM/N2B/M2BTOC.HTM](http://www.project2061.org/publications/rsl/online/COMPARE/NCTM/N2B/M2BTOC.HTM)

Taking Science to School: Participation in Scientific Practices and Discourse, pp. 186-203

Science Curriculum Topic Study: Science as a Human Endeavor, p. 244

Communicating with Drawings, Maps, and Physical Models, p. 229

Use of Computers and Communication Technologies, p. 254

Content Statement	Cumulative Progress Indicator
Ensure that instruments and specimens are properly cared for and that animals, when used, are treated humanely, responsibly, and ethically.	Demonstrate how to use scientific tools and instruments and knowledge of how to handle animals with respect for their safety and welfare. (5.1.12.D.3)

Instructional Focus:

- Selecting and using appropriate instrumentation to design and conduct investigations
- Understanding, evaluating and practicing safe procedures for conducting science investigations
- Demonstrating appropriate digital citizenship (i.e., cyber-safety and cyber-ethics) when accessing scientific data from collaborative spaces. (See [NJCCCS 8.1 and 9.1](#))
- Ensuring that living organisms are properly cared for and treated humanely, responsibly, and ethically

Resources:

National Science Digital Library, Science Digital Literacy Maps

Habits of Mind: Public Perception of Science: <http://strandmaps.nsdl.org/?id=SMS-MAP-2481>

The Nature of Science: Science and Society: <http://strandmaps.nsdl.org/?id=SMS-MAP-1662>

Science Curriculum Topic Study: Scientific Values and Attitudes, p. 248

Council of State Science Supervisors, Science Education Safety:

<http://www.csss-science.org/safety.shtml>

New Jersey Department of Education, Lab Safety Resources:

<http://www.state.nj.us/education/aps/cccs/science/safety.htm>

NSTA Position Statements: Liability of Science Educators for Laboratory Safety:

<http://www.nsta.org/about/positions/liability.aspx>

Responsible Use of Live Animals and Dissection in the Science Classroom:

<http://www.nsta.org/about/positions/animals.aspx>

P.L. 2005, Chapter 266; Dissection Opt Out Law:

<http://www.state.nj.us/education/aps/cccs/science/dissection/>

Science Practices and Verbs (Appendix A)

Categories for Empirical Reasoning	Science Practices	Verbs
Planning, Designing and Data Acquisition	<ul style="list-style-type: none"> • Selection of observation tools and procedures; • Selection of measurement tools and units of measurement; • Selection of productive questions(s); • Understanding interrelationships among central science concepts; and • Use central science concepts to build and critique arguments. 	<p>presents asks responds discusses revises expands challenges critiques knows uses interprets</p>
Data Collection	<ul style="list-style-type: none"> • Observing systematically; • Measuring accurately; • Structuring data; • Setting standards for quality control; • Posing controls, and • Forming conventions. 	<p>examines reviews evaluates modifies generates</p>
Evidence (Data Use)	<ul style="list-style-type: none"> • Use results of measurement and observation; • Generating evidence; • Structuring evidence; • Construct and defend arguments; and • Mastering conceptual understanding 	<p>extends refines revises decides categorizes</p>
Patterns (Modeled Evidence)	<ul style="list-style-type: none"> • Presenting evidence; • Mathematical modeling; • Evidence-based model building; and • Masters use of mathematical, physical and computational tools 	<p>Represents Evaluates Predicts Discovers Interprets Manipulates Build Refines Analyzes Models</p>

<p>Explanation</p>	<ul style="list-style-type: none"> • Posing theories; • Conceptual-based models building; • Search for core explanation; • Considering alternatives; • Understandings how evidence and arguments based on evidence are generated; • Revises predictions and explanations; and • Generates new and productive questions. 	<p>Builds Refines Represents Interacts</p>
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Science Practices and Verbs

Categories for Empirical Reasoning	Science Practices	Verbs
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